ASHRAE TC 9.9 TECHNICAL ALERT

The CDUs Critical Role of TCS and FWS Isolation in Cold Plate Deployments

TL; DR

Ever increasing extreme loads such as AI lack the benefits of best practices or substantial installed base. This ITE costs more than lower density ITE resulting in its damage being a costly risk.

Metallurgy, chip heat transfer, flow, pressure, delta T, etc. can vary greatly between IT platforms, even for the same manufacturer.

There are unintended consequences of developing and / or applying CDUs without understanding why they were originally developed and the critical nuances to the design considerations.

The CDU's role in isolating ITE systems is critical to enabling the rapid growth and scaling of liquid cooling. This is why the best practice is to connect only a single ITE platform to each CDU. Smaller, platform-specific, CDU-isolated TCS loops enable optimal operating environments, simpler maintenance and service, and a scalable architecture where the TCS grows with the ITE deployment.

OVERVIEW

Coolant Distribution Units (CDU) play an important role in liquid cooling of information technology equipment (ITE).

The concept of a coolant distribution unit originated at the time of the IBM S/360 Model 91 announcement in 1964. The CDU concept was originated to guarantee a buffer between customer water and the water flowing through the inter-board heat exchangers within the electronics frames.

The design requirement that the CDU provide a buffer was critical when failures did occur in those early systems due to corrosion of the water carrying components.

With the rapid growth of high-power processors, both graphics processing units (GPU) and central processing units (CPU) for artificial intelligence (AI), and the rapid power densification at the rack level driving adoption of direct to chip liquid cooling (DLC), CDUs are more critical than ever.

The key function that CDUs provide is isolation of the Technology Cooling System (TCS) and Facility Water System (FWS) coolant loops.

This Technical Alert highlights the importance of this isolation and describes best practices for proper CDU integration into a data center environment.

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ISOLATION OF THE TCS AND FWS

Isolation of the TCS from the FWS coolant loops plays a significant role in supporting each of the CDU's key functions. These functions include:

- Clear ownership and control
- Prevention of condensation
- Flexibility of coolants and coolant chemistry
- Temperature & pressure control and protection
- Coolant flow rate management
- Coolant quality control and filtration

There are many benefits of isolation of the TCS and the FWS. Some are obvious and have been covered extensively in other TC 9.9 publications. Several are highlighted here to reinforce.

There are several important benefits of isolation that are less obvious. These need strong consideration and underscore the best practice of connecting only a single ITE platform to each CDU.

OBVIOUS BENEFITS OF ISOLATION

Filtration

Finer filtration to eliminate cold plate clogging

- TCS cold plates often have microchannels that may range from 100 to 500 microns (0.004" to 0.020") in width
- The TCS coolant generally has much different requirements from the FWS, necessitating much finer filtration of the TCS compared to the FWS system.

Chemistry and Materials

Minimizing corrosion and negative material interactions

- Equipment, filtration requirements, and materials in the TCS differ substantially from those in the FWS due to the different functionality of the two systems (i.e., rejecting heat to the outside ambient versus collecting heat from power-dense electronic components located within a controlled environmental envelope), which further differentiates the chemistry and management requirements between the FWS and TCS coolants.
- The chemistry of the TCS coolant must be managed to minimize corrosion and negative material interactions among all the materials in the TCS loop (e.g., an FWS may contain carbon steel, galvanized steel or other materials that are not compatible with the TCS).
- FWS coolant may be required to operate in colder ambient conditions, calling for higher antifreeze concentrations.

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Contamination

Minimizing biological or particulate contamination

- If components of the TCS, such as cold plate loops in ITE, are not carefully cleaned and maintained as required to prevent contamination and biological growth, they can introduce these impurities into the TCS.
- While operational coolant quality maintenance activities should be strictly followed, a CDU further isolates one group of ITE from the rest of the data center, creating a limit to how far such contamination can spread.
- Such isolation also enables localized coolant testing, potentially identifying issues before they cause significant loss of performance and allowing for a localized coolant treatment program.

Temperature & Pressure control

Avoid damage to TCS components

- FWS systems typically operate at much higher system pressure than the TCS due to system sizes and pumping losses. This operating pressure may be higher than the components in the TCS can tolerate.
- CDUs provide stable TCS supply temperature control, given supply temperature and pressure fluctuations of the FWS and changing workloads.

WHY DEDICATE A CDU TO EACH PLATFORM

Vendor Isolation

Isolating ITE systems deployed from different vendors

- ITE suppliers are responsible for the installation, maintenance and service of their equipment. This may include Service Level Agreements (SLA) guaranteeing levels of uptime and compute performance. The only way for the ITE supplier to be able to warrant the operation and performance of their equipment is to specify and control the TCS that provides the thermal management.
- It becomes impossible for ITE vendors to ensure adequate cooling and uptime if they do not monitor and control the TCS.

    1. Temperature, pressure and flow rate requirements differ
    2. Flow and pressure instability caused by the actions of a different ITE supplier's equipment may disrupt performance
    3. Contamination with particles, biology, or even air bubbles may create the need for expensive maintenance or replacement of damaged/contaminated components of the TCS. The source of this contamination may be difficult to trace, leading to disputes between ITE suppliers and delays in providing the required service.

- In the event of a system failure, a required step may be to shut down the CDU on the TCS. While many systems deploy redundant CDUs, the shutdown would impact cooling from all vendors' systems for the fault of one.

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Platform Requirements

Managing platform-specific requirements

- ITE requires a specific inlet temperature and pressure differential to ensure sufficient heat transfer and flow through the ITE TCS components for operation within stated thermal specifications. These requirements are often different between platforms, even for systems provided by the same vendor.
- A CDU isolates each zone of ITE and can ensure the specific temperature and pressure requirements for each platform.
- If a CDU is required to provide cooling to multiple systems, each with a different pressure differential, the CDU must be set to the highest-pressure differential required by any ITE on the TCS. Flow balancing valves or other pressure loss devices must be used to balance the flow. The necessary use of balancing valves will increase the energy consumption of a system compared to multiple systems with CDUs zoned to specific ITE solutions.

CapEx

Optimizing CapEx spend

- Although ever increasing CDU size is tempting, it potentially has a disproportionally high risk due to its size being unproven.
- By isolating incremental ITE deployments with CDUs, data center operators can add TCS capacity as the business grows rather than requiring a large investment at the time of data center construction.

Blast Radius

Minimizing the blast radius

- The blast radius is defined as the number of ITE impacted by a CDU service outage, whether due to maintenance or an operational fault.
- While most CDUs are designed with robust redundancy and serviceability features, maintenance is required, and failures do occur.
- Regular maintenance of the TCS could be required. While CDUs are often designed for concurrent maintainability, it is critical to acknowledge that not all CDU components can be serviced without impacting the cooling system. For example, the heat exchanger within a CDU is not concurrently maintainable, and failure may necessitate a full replacement. The impact of a TCS failure or maintenance outage is better managed by isolating smaller segments with different CDUs.
- Operators should establish clear expectations regarding Mean Time to Repair (MTTR) in the event of a catastrophic failure. Backup CDU strategies should be considered to mitigate risks, especially in high-reliability environments where liquid cooling downtime could impact ITE SLAs.

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Scalability

Enabling scalability

- Rack power density regularly exceeds 100 kW for AI applications in 2025, and roadmaps are indicating that 500 kW or higher by 2030. With rack power increasing so rapidly, a large CDU and TCS piping network intended to cool a data hall will soon be cooling a row or even just a few racks. Building out smaller, CDU-isolated domains that can be more easily upgraded will often be more cost- and time-effective.
- While CDUs may be deployed in parallel configurations to add capacity, pipe sizing is limiting.
- TCS coolant, material compatibility, and cleanliness requirements may drive up costs for deployments of large diameter pipes. It is generally more cost-effective to distribute FWS coolant at scale.

Summary

A CDU performs critical roles in managing condensation, coolant temperature, coolant flow, and coolant quality for the TCS. CDUs also provide a critical role in isolating ITE systems in smaller, more manageable building blocks that enables the rapid growth and scaling of liquid cooling.

The operator is encouraged to check the compatibility of TCS requirements for different ITE systems and ensure that systems attached to a single CDU have compatible requirements. One approach to this would be to avoid large multivendor TCS loops and to be aware that TCS requirements may differ with the same ITE vendors product portfolio due to the high projected power-density growth-rate.

Smaller, platform-specific, CDU-isolated TCS loops enable optimal operating environments, simpler maintenance and service, and a scalable architecture where the TCS grows with the ITE deployment.

The ASHRAE TC 9.9 Datacom Encyclopedia provides additional information on CDUs, including various implementations, design considerations and controls.

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